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(71) Applicant: SUMITOMO ELECTRIC INDUSTRIES, LTD.
Osaka-shi, Osaka (JP)

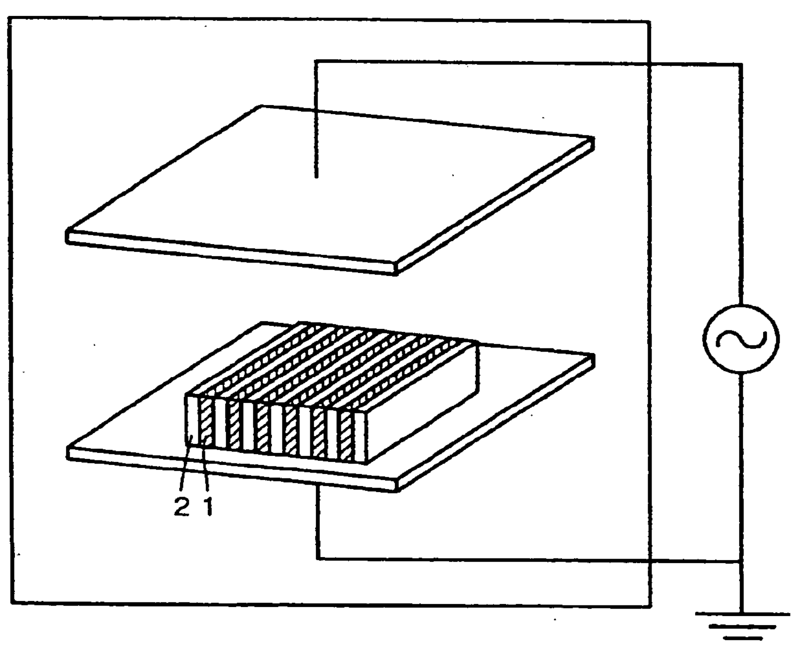
(72) Inventors:
- Shiomi, Hiromu c/o Itami Works of Itami-shi, Hyogo (JP)
- Kumazawa, Yoshiaki c/o Itami Works of Itami-shi, Hyogo (JP)

(74) Representative:
Cross, Rupert Edward Blount et al
BOULT WADE TENNANT,
27 Furnival Street
London EC4A 1PQ (GB)

(54) Method of manufacturing diamond heat sink

(57) A diamond polycrystal body having metal films on its upper and lower surfaces is prepared. The diamond polycrystal body is cut in the vertical direction to form a diamond polycrystal body piece (1) having upper and lower surfaces and a cut surface connecting the upper and lower surfaces. The cut surface of diamond polycrystal body piece (1) is plasma-treated. A method of manufacturing a diamond heat sink removed of a damage layer on its cut surface and having prescribed insulation is thus provided.

FIG. 2



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SEARCH REPORT

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Description

The present invention relates generally to methods of manufacturing a diamond heat sink, and more particularly, to a method of manufacturing a diamond heat sink produced by metallizing a diamond surface formed by means of vapor phase synthesization.

In association with developments in the high information-intensive society, the performance of semiconductor devices such as semiconductor laser diode and IMPATT diode used for transmitting information have been remarkably improved. In order to further improve the performance of these semiconductor devices, thermal energy generated from these devices should be radiated to restrict temperature increase. The heat sink is used for such heat radiation. The material known as the best for the heat sink was II a type natural diamond.

Meanwhile, heat sinks have been produced using synthetic diamond, and such heat sinks exhibit high thermal conductivity comparable to II a type natural diamond, with a smaller variation in quality, and therefore have stable heat radiation performance, contributing to improvements in the performance/reliability of various semiconductor devices and prolonging the life of the devices.

The present invention relates to a method of manufacturing a diamond heat sink produced by metallizing a surface of such synthetic diamond, in other words diamond synthesized by means of vapor phase synthesization.

Five specific examples of a conventional method of manufacturing a diamond heat sink will be now described. In a first conventional example, a diamond polycrystal body is cut into pieces of a prescribed shape by a diamond saw. The diamond pieces cut into a prescribed shape are arranged close to each other and metallized. Metallizing the upper and lower surfaces completes the diamond heat sink.

In a second conventional example, a diamond polycrystal body is cut into pieces of a prescribed shape by a diamond saw. After metallizing the entire surface, an end faces are ground using a grind stone to leave the metal film only at the upper and lower surfaces and the diamond heat sink is completed.

In a third example, a diamond polycrystal body having its surface metallized is cut into pieces of a prescribed shape by a diamond saw to complete a diamond heat sink.

In a fourth example, as disclosed by Japanese Patent Laying-Open No. 5-11467, after metallizing the surface of a diamond polycrystal body, grooves are made in the diamond using a laser, followed by mechanical separation to complete a diamond heat sink.

In a fifth conventional example, diamond is cut into pieces of a prescribed shape by a laser. The conductive portion of each end face is removed by means of an oxidation treatment, and then the pieces are arranged close to each other for metallization. Thus metallizing the upper and lower surfaces completes a diamond heat sink.

Diamond heat sinks have been conventionally manufactured as described above.

In a cutting method using a diamond saw, however, a diamond polycrystal body cannot be highly precisely cut or a large margin is necessary for cutting.

A margin for grinding should be further taken into account for grinding. A method using a laser provides precise cutting, but a conductive layer (graphite layer) is sometimes formed at a cut surface due to damages caused by the laser. An oxidation treatment to remove the conductive layer is therefore necessary. In that case, after a diamond polycrystal body is cut into pieces of a prescribed shape, metallization should be performed. However, after cutting a diamond polycrystal body into pieces of a prescribed shape, metallization with a complicated pattern using photolithography or the like cannot be performed.

Furthermore, in the above-described method of making grooves using a laser after metallizaion, a chip portion is formed at an end surface in the final mechanical separation process.

The present invention is directed to solutions to the above-described problems, and it is an object of the invention to provide an improved method of manufacturing a diamond heat sink which permits precise and efficient processing.

In a method of manufacturing a diamond heat sink according to the present invention, a diamond polycrystal body having metal films on its upper and lower surfaces is prepared. The diamond polycrystal body is cut in the vertical direction to form diamond polycrystal body pieces having upper and lower surfaces and a cut surface connecting the upper and lower surfaces. The cut surface of the diamond polycrystal body piece is subjected to plasma treatment.

Since the cut surface of the diamond polycrystal body piece is plasma-treated, damages on the cut surface are removed, a diamond heat sink having a prescribed insulation property is obtained.

According to a preferred embodiment of the invention, a diamond polycrystal body is cut using a YAG laser or an exima laser, and therefore precise and efficient processing may be achieved.

According to the preferred embodiment of the invention, the above-described plasma treatment is performed using oxygen, halogen, a halogen compound or an inert gas. Thus, diamond having a clean surface results.

According to the preferred embodiment of the invention, the above-described plasma processing is performed while protecting the surface other than the cut surface using a resin film softer than the metal film.

According to another preferred embodiment of the invention, CF_4 is used as a halogen compound to optimize the CF_4/O_2 percentage. If CF_4 exceeds 70 %, the effect of damaging a metallized layer exceeds the effect

of removing a damage layer on diamond, CF_4 is desirably not more than 70 %. In order to minimize damages given to the metal film, the percentage is preferably not more than 50 %.

Damaged layers of diamond may be removed using only oxygen, but the percentage of CF_4/O_2 is desirably not less than 5 %. Thus, the diamond surface after removal of the damaged layers is flat.

Damages are removed such that the electrical resistance of the upper and lower surfaces of the diamond heat sink is not less than $1 \times 10^6\ \Omega$. The value is an insulation resistance value generally necessary for a semiconductor laser, and the performance of a semiconductor laser is lowered with resistance less than the value.

Since a diamond polycrystal body having a thermal conductivity of at least 5 w/cmK is used, the resultant heat sink can achieve sufficient performance.

The foregoing and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings and given by way of example.

Fig. 1 is a chart showing a process of manufacturing a diamond heat sink;

Fig. 2 is a view showing a main step in a method of manufacturing a diamond heat sink according to a first embodiment;

Figs. 3A and 3B are views showing a first step in a main part of a method of manufacturing a diamond heat sink according to a second embodiment of the invention;

Figs. 4A and 4B are views showing a second step in the main part of the method of manufacturing a diamond heat sink according to the second embodiment; and

Fig. 5 is a view showing a third step in the main part of the method of manufacturing a diamond heat sink according to the second embodiment.

Fig. 1 is a process chart schematically showing a method of manufacturing a diamond heat sink according to one embodiment of the invention. A polycrystal diamond body is manufactured. The polycrystal diamond body is metallized, and metal films (also referred to as metallized layers) are formed on the upper and lower surfaces of the diamond body. The metal films are patterned. The patterning of the metal films will be later described. The diamond polycrystal body are cut in the vertical direction into diamond polycrystal pieces having upper and lower surfaces and a cut surface connecting the upper and lower surfaces. The cut surfaces of the diamond polycrystal pieces are plasma-treated for insulation.

Embodiments of the invention will be now described in conjunction with the accompanying drawings.

First Embodiment

A diamond polycrystal body was synthesized by means of filament CVD. The diamond polycrystal body was formed to have a size of 0.3 mm in thickness and 25.4 mm in both longitudinal and transverse directions. The polycrystal body was finished into a thickness of 0.25 mm by grinding processing.

Metal films were formed both on the upper and lower surfaces of thus ground diamond polycrystal body in the order of Ti, Pt, Au and a gold-tin alloy by means of sputtering. Ti is as thick as 600 Å, Pt 800 Å, Au 10000 Å and the gold-tin alloy 30000 Å.

The upper surface of the uppermost metal film was applied with photoresist by means of spin-coating, a pattern corresponding to a device to be packaged was transferred onto photoresist by means of photolithography, and a metal film pattern was formed by means of ion beam etching.

The diamond polycrystal body having the metal film pattern was cut into a lattice, to form a diamond polycrystal body heat sink (also referred to as polycrystal body pieces). The resulting diamond polycrystal body heat sink was damaged by a YAG laser, a graphite layer is formed on the diamond cut surface, which attained conductivity and the resistance of the upper and lower surfaces was not more than $10^2\ \Omega$.

Referring to Fig. 2, diamond heat sink 1 and a buffer member 2 of Teflon resin were placed upon each other and introduced into a reactive ion etching device (RIE device) so that the cut surface is exposed to plasma. By placing buffer member 2 and heat sink 1 upon each other as shown, only the cut surface is subjected to plasma and the surfaces of the metal films will not be exposed to plasma. Etching was conducted with 50 sccm oxygen, and 20 sccm CF_4 at an RF power of 300 W and under the total pressure of 50 mTorr for 1 minute.

As a result, a damage layer of the cut surface was removed and the resistance between the upper and lower surfaces was $5 \times 10^9\ \Omega$, in other words a prescribed insulation was secured.

Second Embodiment

A diamond polycrystal body was synthesized by microwave plasma CVD. The diamond polycrystal body was formed into a size of 0.8 mm in thickness and 30 mmϕ. The diamond polycrystal body was then finished into a thickness of 0.6 mm by grinding processing. On the upper and lower surfaces of the ground diamond polycrystal body, Ti, Pt, Au and a gold-tin alloy were deposited in this order by means of vapor deposition to form metal films. The thicknesses of Ti, Pt, Au, and the gold-tin alloy were 500 Å, 400 Å, 10000 Å, and 50000 Å, respectively.

As is the case with the first embodiment, a metal film pattern was formed on the upper surface by means of photolithography. The diamond polycrystal body hav-

ing the patterned metal film was cut into 6 mm × 2 mm pieces by a YAG laser. The polycrystal body pieces had damages caused by the YAG laser, their cut surfaces attained conductivity, and the resistance of the upper and lower surfaces of the diamond polycrystal body pieces was not more than $10^3\ \Omega$.

Referring to Fig. 3A, a jig 3 having an opening 3a to hold diamond polycrystal body piece 1 upright is prepared. Diamond polycrystal piece 1 is held upright in jig 3. At the time, polycrystal body piece is fixed in jig 3 such that the cut surface of polycrystal body piece 1 is exposed. Fig. 3B is a plan view showing how diamond polycrystal body piece 1 is set in the opening 3a of jig 3.

Referring to Fig. 4A, a metal film mask (as thick as 50μm) 5 having a slit 6 for exposing the cut surface of diamond polycrystal body piece 1 is placed on jig 3. Metal mask 5 is provided to prevent oxygen ions from coming into the gold-tin alloy surface provided on diamond polycrystal body piece 1. Fig. 4B is a partial plan view showing how metal mask 5 is placed on jig 3.

Referring to Fig. 5, jig 3 having metal mask 5 fixed thereon is introduced into the RIE device for RIE processing. The etching was conducted at the total pressure of 10 mTorr, and on RF power of 300 W with 50 sccm O_2 for 30 minutes.

Referring to Fig. 5, a graphite component of diamond polycrystal body piece 1 formed by damages given by a YAG laser was etched away by oxygen ion plasma 7, and the resistance of the upper and lower surfaces was $4\times10^9\ \Omega$, in other words prescribed insulation was secured.

As in the foregoing, according to the present invention, a cut surface of a diamond polycrystal body piece is plasma-treated, and therefore a graphite component formed on the cut surface is etched away, so that prescribed insulation is advantageously secured.

Claims

1. A method of manufacturing a diamond heat sink, comprising the steps of:

   preparing a diamond polycrystal body having metal films formed on its upper and lower surfaces;
   cutting said diamond polycrystal body in the vertical direction, thereby forming a diamond polycrystal body piece (1) having upper and lower surfaces and a cut surface connecting the upper and lower surfaces; and
   plasma-treating said cut surface of said diamond polycrystal body piece (1).

2. A method as claimed in claim 1, wherein said diamond polycrystal body is cut using a YAG laser or an exima laser.

3. A method as claimed in claim 1 or claim 2, wherein said plasma-treatment is performed using oxygen, a halogen, a halogen compound or an inert gas or a mixture of two or more thereof.

4. A method as claimed in any one of the preceding claims, wherein the plasma-treatment of said cut surface of said diamond polycrystal body piece (1) is performed by masking the surface other than said cut surface with resin (2) which is softer than said metal film.

5. A method as claimed in claim 1, wherein said plasma-treatment of said cut surface of said diamond polycrystal body piece (1) is performed using a metal mask (5) to mask said upper and lower surfaces so that said plasma is prevented from coming into said upper and lower surfaces of said diamond polycrystal body piece (1).

6. A method as claimed in any one of the preceding claims, wherein said plasma-treatment is performed until the electrical resistance between said upper and lower surfaces becomes at least $1\times10^6\ \Omega$.

7. A method as claimed in any one of the preceding claims, wherein said diamond polycrystal body has a thermal conductivity of at least 5 w/cmK.

8. A method as claimed in any one of the preceding claims, wherein said plasma treatment is performed using O_2 and CF_4.

9. A method as claimed in claim 8, wherein CF_4/O_2 does not exceed 70 %.

10. A method as claimed in claim 9, wherein CF_4/O_2 is in the range of from 5 % to 50 %.

FIG. 1

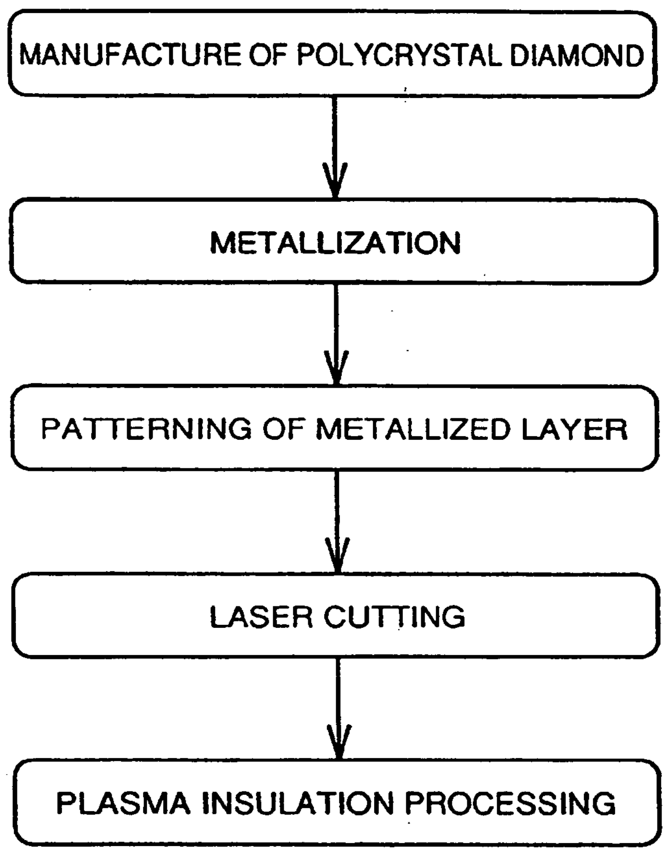

MANUFACTURE OF POLYCRYSTAL DIAMOND
METALLIZATION
PATTERNING OF METALLIZED LAYER
LASER CUTTING
PLASMA INSULATION PROCESSING

FIG. 2

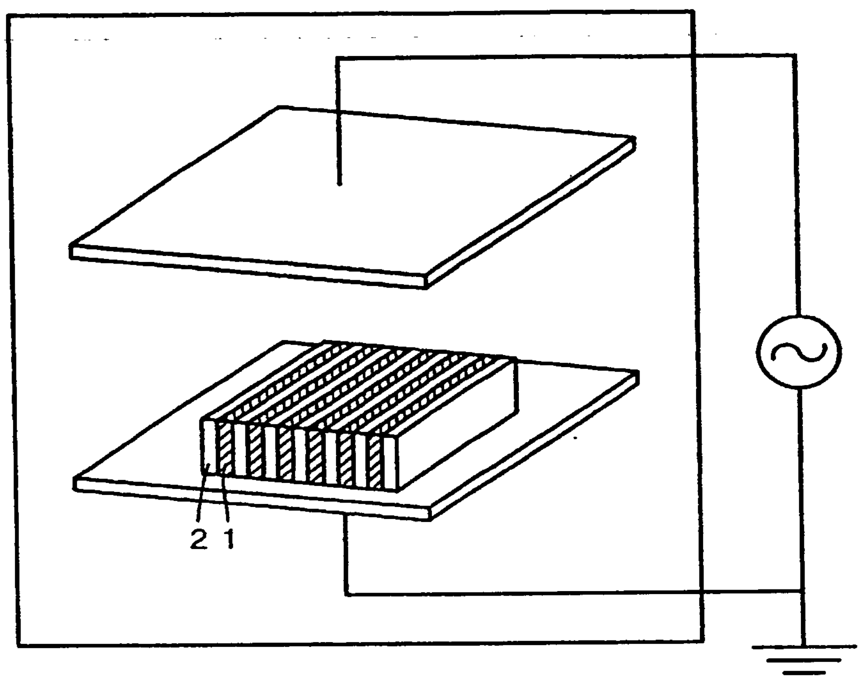


FIG. 3A

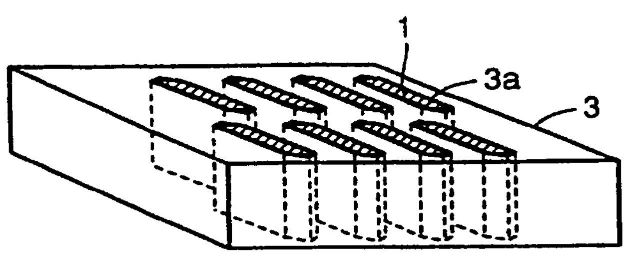


FIG. 3B

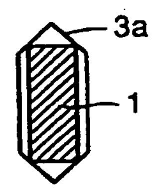


FIG. 4A

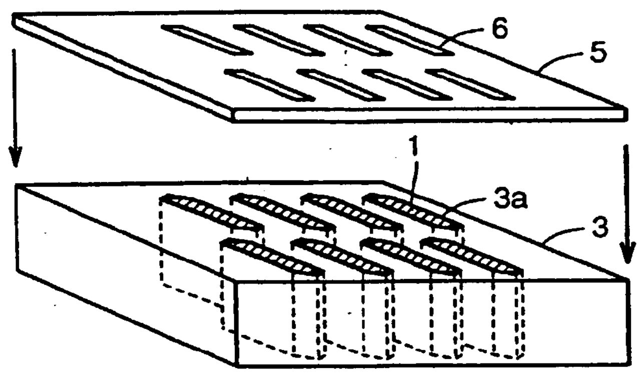


FIG. 4B

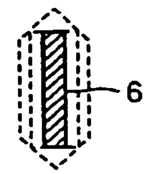
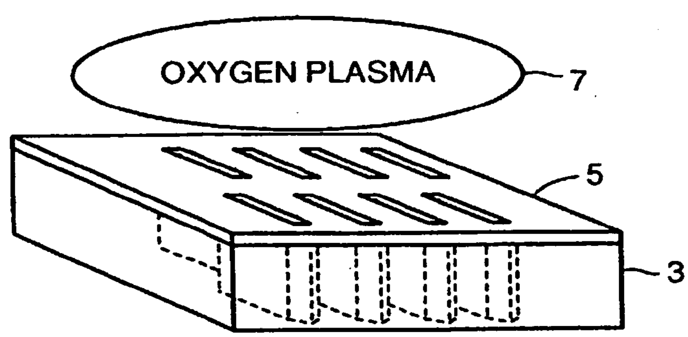


FIG. 5



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Osaka-shi, Osaka (JP)

(72) Inventors:
- Shiomi, Hiromu c/o Itami Works of Itami-shi, Hyogo (JP)
- Kumazawa, Yoshiaki c/o Itami Works of Itami-shi, Hyogo (JP)

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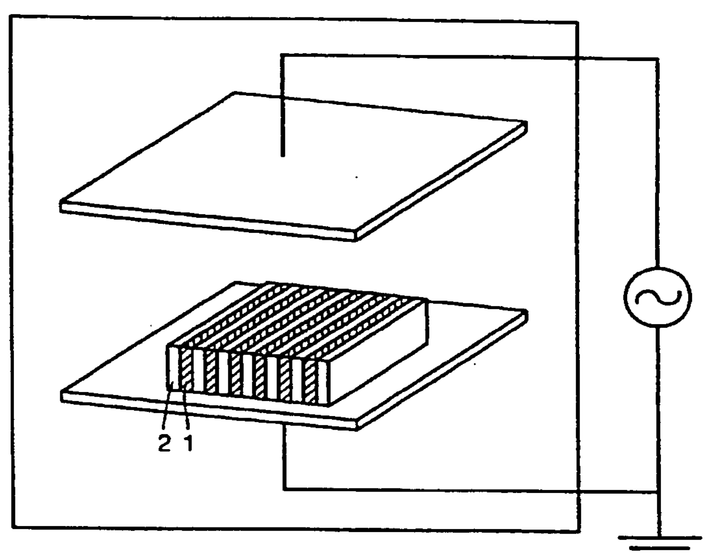

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EUROPEAN SEARCH REPORT

Application Number
EP 98 30 0865

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A	PATENT ABSTRACTS OF JAPAN vol. 095, no. 005, 30 June 1995 & JP 07 040336 A (SUMITOMO ELECTRIC IND LTD), 10 February 1995 * abstract * -/--	1	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	24 November 1998	Munnix, S

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
O : non-written disclosure
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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
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A	EP 0 442 006 A (DRESCHHOFF GISELA A M ;ZELLER EDWARD J (US)) 21 August 1991 * abstract * ---	1	
A	HUNN J D ET AL: "ION BEAM AND LASER-ASSISTED MICROMACHINING OF SINGLE-CRYSTAL DIAMOND" SOLID STATE TECHNOLOGY, vol. 37, no. 12, 1 December 1994, pages 57-60, XP000485595 * page 58, right-hand column, paragraph 2 * ---	1	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
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